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Biodiversity: Which Communities are Hiding It?

MICHAEL B. USHER

Scottish Natural Heritage, 2 Anderson Place, Edinburgh EH6 5NP, UK

Introduction

Since at least the time of Linnaeus' writings there has been a considerable interest in the variety of life on this planet. Within the last few years, the word 'biodiversity' has been used to summarize the growing interest in this variety of life. Biodiversity, as a term, summarizes the genetical variation either of the whole planet or the genetical variation that occurs naturally within a limited geographical area. Thus, it is concerned with the number of species that exist, together with the genetic variation within each of those species. It is often confused with the term 'species richness', which relates simply to the number of species and not to the genetical variation within those species.

The species richness of the planet is currently unknown. Wilson (1988) summarized the numbers of described species, showing that there are of the order of 1000 species of Virus, 5000 of Monera, 47 000 of Fungi, 27 000 of Algae, 428 000 of Plantae, 31 000 of Protozoa, 990 000 of Animalia and 44 000 of Chordata (all have been rounded to the nearest thousand). There has been considerable speculation about how many species there actually are, remembering that the majority of species in some groups have now been found and described (for example the birds and mammals), whereas in other groups only a very small proportion have been described (for example many of the arthropods). Estimates of the rate of species loss vary wildly (Lugo, 1988) with no consensus amongst scientists, other than that a large proportion of all species, with estimates between 33% to well over 50%, will be extinct by the end of the next century if present trends continue. There has been a particular

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emphasis on some of the communities that are known to be particularly species rich, such as tropical rainforests and coral reefs.

The aim of this paper is to consider the species richness that is found in some habitats in the British Isles. The focus of conservation attention has tended to be on some well-known species-rich communities such as chalk grasslands (Duffey *et al.*, 1974) and ancient woodlands (Peterken, 1981). However, there has also been interest in the geographical variation in the richness of some groups of arthropods, for example the British butterfly and moth species (Turner, Gatehouse and Corey, 1987) where the number of species declines in a northerly direction and is apparently related to the amount of sunshine during the summer (May–September) period. Such geographical studies, or studies attempting to locate 'hot spots' of biodiversity, are not the aim of this paper. The aim is, however, to suggest that many communities have an unrecognized species richness, and hence that there is a need to be cautious about sweeping generalizations concerning some geographical areas or some particular habitat types.

Three case studies

The fauna of acidic soils

The difficulty of working in the soil ecosystem was emphasized by Coleman (1985). There are considerable challenges to working with organisms that live in this three-dimensional, opaque environment, being an intimate mixture of mineral particles that form the soil, their water coating, and air in the spaces between them. Add to this the ramification of plant roots and fungal and Actinomycete hyphae, and one realizes that structurally the soil environment is extremely complex. Any attempt to sample this environment destroys its spatial relationships. As Phillipson (1971) has pointed out, there is no way of sampling the whole soil fauna and microbial communities with a single sample; each group of animals or microbes needs to be extracted from the soil in a different way.

Wallwork (1976) published a list of characteristic densities of some of the major groups of soil animals. Quoting a variety of studies, he showed that testate protozoa could have a density of in excess of $10^7\,m^{-2}$ and that nematodes in grassland soil would have a density of $4\text{–}20 \times 10^6\,m^{-2}$. In podsolized soils, the enchytraeid worms could have a density in excess of $10^5\,m^{-2}$ and arthropods (Collembola and Acari) may well have a density of up to $5 \times 105\,m^{-2}$. Although the density of individuals is clearly very great when measured in relation to the soil surface rather than the surface area of all of the soil particles, how does this relate to the species richness of these groups of organisms?

The taxonomy of many of the groups of soil organisms is so imperfectly known that it is not yet known how many species are involved. If one of the smaller groups, Collembola, is considered, then it is known that the

species richness is not particularly great (Usher *et al.*, 1979). The richness on any particular habitat (field, forest plantation, fen, etc.) is of the order of 15–25 species. However, it is known that the diversity of Acari is considerably greater, with perhaps of the order of 100–150 species in an equivalent habitat. There is, therefore, quite a considerable species richness within soil ecosystems, but the extent of that richness is at present unknown (Petersen, 1982). It is this richness that has led J. M. Anderson (pers. comm.) to refer to the soil as the 'poor man's tropical rain forest'.

Invertebrates of upland heathlands

The upland heathlands of Britain appear, at first sight, as if they are a monoculture of heather, *Calluna vulgaris*, with relatively little diversity. A survey of ten upland heathlands within the area of the North Yorks Moors National Park (Usher and Thompson, in press) yielded a total of 40 vascular plant species (*Table 1*). As expected *C. vulgaris* was the most abundant, with few other plants gaining local cover values in excess of 1%. The species richness of these upland heathlands therefore represents just over 2% of the British vascular plant flora. However, there were small areas dominated by *Sphagnum* spp., and under the stands of mature and degenerate *C. vulgaris*, as well as on recently burnt areas, there were well developed stands of bryophytes. The 31 species recorded represent 4.5% of the British bryophyte flora. Botanically, these upland heathlands are therefore species poor.

Usher (1992) analysed the abundance of two groups of arthropods on these heathlands. The ground beetles (Coleoptera: Carabidae) are relatively species rich, with 54 species representing 15% of the British fauna. It is notable (*Table 2*) that one species tends to dominate the ground beetle community. In contrast, there is very little dominance of the community by one or a few spider species. Just over 20% of the British fauna was sampled on these ten heaths (*Tables 1* and *2*).

Table 1. Comparative data for the numbers of species recorded on 10 upland heathlands within the North York Moors National Park.

Species group	Number of species	% of British flora/fauna
Vascular plants	40	2.2
Mosses (bryophytes)	31	4.5
Birds	27	11.7
Ground beetles (Carabidae)	54	15.3
Spiders (Araneae)	127	20.4

Table 2. The species richness of spiders (Araneae) and ground beetles (Coleoptera: Carabidae) at 62 sites located on 10 upland heathlands within the North York Moors National Parks. Juveniles of both groups have been excluded.

Species	Total number caught	Percentage of total (%)	Number of site occurrences
Ground beetles			
Trechus obtusus Erichson	1328	21.0	48
Calathus melanocephalus (L.)	703	11.1	44
Carabus problematicus Herbst	549	8.7	51
Nebria salina Fairm. & Lab.	508	8.0	24
Olisthopus rotundatus (Paykull)	343	5.4	35
Calathus micropterus (Dufts.)	292	4.6	18
Agonum fulginosum (Panzer)	282	4.5	21
Trichocellus cognatus (Gyll.)	269	4.2	44
46 other species	2062	32.5	–
Spiders			
Pirata piraticus (Clerck)	561	8.4	19
Lepthyphantes zimmermanni Bertkau	416	6.3	47
Robertus lividus (Blackwall)	355	5.3	51
Pelecopsis mengei (Simon)	338	5.1	46
Gnaphosa leporina (L. Koch)	330	5.0	41
Antistea elegans (Blackwall)	286	4.3	13
Lepthyphantes ericaeus (Blackwall)	280	4.2	58
Pardosa palustris (L.)	276	4.1	27
Allomengea scopigera (Grube)	274	4.1	24
118 other species	3572	53.2	–

Table 3. A comparison between Danby Low Moor (altitude 260 m above sea level) and Danby High Moor (altitude 410 m above sea level). The areas of search and the intensity of trapping are identical on the two heathlands. The % figures represent the percentage of the British fauna or flora of that taxon found on the individual heathland.

	Danby Low Moor		*Danby High Moor*	
Taxon	No.	%	No.	%
Vascular plants	9	0.5	5	0.3
Mosses and liverworts	12	1.6	9	1.2
Ground beetles (Carabidae)	39	11.0	42	11.9
Spiders	96	15.4	81	13.0

The diversity becomes even more remarkable when individual heathlands are compared (*Table 3*). The diversity of the plants, both vascular plants and bryophytes, is extremely low. However, the diversity of the two groups of arthropods is much higher. There is, therefore, a considerable diversity of these taxonomic groups within what may be perceived to be uniform stands of vegetation.

However, this particular vegetation type is maintained as a mosaic of heather stands of differing age by burning. There are, therefore, patches of different successional age spatially spread across these heathlands. There is also temporal variability, since these patches are changing in time, as the heather goes through its pioneer, building, mature and degenerate phases (Gimingham, 1972). There is therefore a spatially and temporally complex system of patches. Although there is no evidence yet that size variability in these patches is important for invertebrates, there is increasing evidence that size is important for birds (Usher and Thompson, in press). Large patches favour species such as golden plover, curlew, lapwing and possibly also skylark. Small patches, probably managed on two burning regimes of different time periods so that some heather becomes degenerate, favour many species including red grouse, merlin, short-eared owl and whinchat. An intermediate patch size provides many edges which are used as nest sites by meadow pipits (D. Allan, pers. comm.). There is some evidence that the diversity of these upland heathlands is being favoured by the current management regime for grouse moors.

Plants and animals in farm woodlands

Farm woodlands in the Vale of York have recently been studied (e.g. Usher, Brown and Bedford, 1992). The Vale of York is low lying, composed of glacial deposits overlying Triassic sandstones, and south of the City of York probably contains no areas of semi-natural woodland. In a survey of 33 farm woodlands planted from 20–90 years ago, and primarily managed for pheasant cover, 54 species of trees and shrubs and 133 species of herbaceous plants were found. Although the trees and shrubs were introduced, most of the herbaceous plants would either have been on site at the time of planting, or would have arrived in the woodlands subsequent to planting. Usher, Brown and Bedford (1992) showed that there is a species-area relationship, whereby larger woodlands tend to have more plants than smaller woodlands. The rate of increase in species with woodland area indicates that the number of species doubles if the area increases by a factor of approximately 11.5. There is also some evidence from these 33 woodlands that the species indicative of ancient woodlands (listed for North Yorkshire by R. Gulliver, pers. comm.) only occur in the larger woodlands. Thus, although *Hyacinthoides non-scripta* occurred in some of the smaller woodlands, it was only consistently occurring in woodlands over 5 ha. *Veronica montana*, *Oxalis acetosella* and *Primula vulgaris* are woodland indicator species that did not occur in the smallest woodlands, but had a probability of 0.5 or more of occurring in woodlands of 5 ha and over. Thus, although the farm woodlands had a considerable diversity of vascular plants (about 9% of the

British flora), it was only the larger farm woodlands that tended to have the characteristic woodland species. A survey of the moths in 18 of these woodlands (S. W. Keiller, pers. comm.) has indicated a total of 211 species, representing approximately 25% of the British fauna of the Macrolepidoptera. As might be expected for a group of herbivores, there is a positive correlation between the moth species richness and the plant species richness. In a survey of the spiders and ground beetles in 28 of these farm woodlands, 106 species of spiders (17% of the British fauna) and 48 species of ground beetles (13.6% of the British fauna) were found (Usher, Field and Bedford, 1993).

Unlike the upland heathlands, there was considerable plant species and structural diversity in these farm woodlands. The data for both herbivorous and predatory arthropods has indicated that there is a considerable species richness in these woodlands as well as the habitats discussed above.

Conservation implications

The results of studying three habitats in Britain – acidic soils, upland heathlands and farm woodlands – have indicated that each has a very considerable species richness. This raises the question of whether all communities are inherently species rich. Chalk grasslands, ancient woodlands and fenlands have been suggested as centres of biodiversity in Britain. However, should one be considering other habitats as well? It may be that there are species that occur in all habitats, and hence these farm woodlands, upland heathlands, etc. are just recording a suite of ubiquitous species. Alternatively, it may be that these habitats are important in their own right and have largely been overlooked by collectors and recorders. The indication that the charactistic woodland plant species occurred in farm woodlands larger than 5 ha suggests that the smaller woodlands contain that ubiquitous set of species, whereas the larger woodlands contain genuine woodland species as well. The inclusion of spiders such as *Gnaphosa leporina* in *Table 2* indicates that the upland heathlands also have characteristic species. The species richness of these less obviously species-rich sites is therefore something that needs to be considered carefully.

An important question to answer is how this species richness changes in time. It has been suggested that part of the species richness of the upland heathlands is due to the patch structure being dynamic in both space and time. Similarly, the farm woodlands in the Vale of York, having been planted less than 100 years ago, are still developing as woodlands. There is no evidence from short term studies to indicate dynamic changes but it is likely that the range of ages has contributed to a range of successional stages, and hence has probably increased the apparent species richness. Variation in time would therefore seem to be one factor that contributes towards species richness.

The spatial mosaic of ecosystems is obviously something that is important. The current pattern of land use, leaving fragments of semi-natural vegetation, or creating fragments of other vegetation, imposes on species a number of constraints. How long will populations remain within fragments that have been

created from a previously more extensive habitat type? How long will it take new habitat types to be colonized by either the more general species or the species more characteristic of that new habitat type? In the farm woodland studies, the boundary of the farm woodland was marked by a very abrupt change in the communities of soil Collembola and Acari (S. Sgardelis, pers. comm.). The majority of the arthropod species occurring within the woodland soils are not occurring in the arable fields, even within a few metres of the woodland margin. It seems, therefore, difficult to understand how these small arthropods move from woodland to woodland. Many of the larger arthropods are capable of flight, and indeed for the most mobile groups of arthropods, e.g. noctuid moths, there was no relationship between the number of species in a farm woodland and its area (S. W. Keiller, pers. comm). For an even more mobile group of animals, the small mammals, there is evidence to suggest that there is a considerable movement of individuals from woodland to woodland (Zhang and Usher, 1991). Species richness is therefore likely to be related to the mobility of the organisms studied. This may be their own ability to fly or run from fragment to fragment, or related to their ability to 'hitch a lift' with people (Woodruffe-Peacock, 1918).

This relates to species richness, and not to biodiversity, which also measures the genetic variation within populations. The work of Ehrlich and Murphy (1987) has shown that there may be very limited gene flow between small, isolated populations. However, in the kind of habitat fragments which have been discussed here, there is likely to be an element of gene flow, particularly for the more mobile species. The extent of this gene flow may be variable since some potentially mobile species do not move far in colonizing new habitats (C. D. Thomas, Chapter 29). Insufficient is yet known about the management of metapopulations, clusters of populations with limited genetic interchange between them.

The term 'biodiversity' contains two components; the number of species and the genetic variability within those species. It is a relatively easy task to count the number of species, though of course all counting depends upon sampling and hence the counts are likely to be under-estimates. However, almost nothing is known about the genetic variability that exists in wild populations. Conservation activities are generally aimed at retaining the maximum number of species. In doing this, we have a complicated system of nature reserves, national parks, etc. as well as programmes for the wider countryside, including some of the less obviously species-rich habitats that are previously described. However, very little is known about whether these activities are also protecting the genetic variability of the species. In a fragmented landscape, a mosaic of many different habitat types, many populations are becoming isolated and potentially genetically more homogeneous. Is it therefore true that biodiversity is being eroded at the genetic level? There is as yet no answer to this question. However, the configuration of patches of habitat within the landscape may be important, some species living in an insular way in patches and others ranging over several patches. These latter could become endangered if the spacing between patches is too large, if the occurrences of particular combinations of

patches (the mosaic structure) becomes too rare, or if there is dominance by a particular and unsuitable patch type. Particular components of the total species richness may require the conservation of a particular landscape type.

If the biodiversity of this planet is to be protected, then both aspects of biodiversity, the species richness and the genetic variability, must be given equal emphasis. These need to be judged in the context of habitats and landscapes. But, more importantly, conservation activities must not be concentrated on just a few habitat types; a whole range of habitats have a real contribution to make to the world's biodiversity.

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